SECTION 5 - LOCK CAPACITY AND DELAY FUNCTION ESTIMATION

OVERVIEW

As traffic levels increase on a waterway, the increased traffic creates delays at bottlenecks on the system. Generally, these bottlenecks or constraints occur at navigation locks. Quantifying the relationship between tonnage moving through a lock and the delay at the lock is essential to the economic analysis of the value of the navigation system.

There are two distinct ways to establish the delay-tonnage relationship of lock operations--deterministically or through simulation. In this study, the deterministic approach was used for all system locks except IHNC, whereas for the IHNC lock, simulation was used. Simulation was considered more appropriate for IHNC due mainly to the fact that simulation analysis would be more adept at calculating the impacts of bridge operations on navigation and simulation would also be better suited for measuring the relative efficiencies of chamber packing with different size chambers. The following is a discussion of the deterministic approach and simulation approach selected for this study.

DETERMINISTIC APPROACH

The deterministic technique selected for use in this study is an "engineered" approach which estimates the capacity at a system lock by analyzing the distribution of service times as a function of lock operating procedures and the distribution of tonnage present for processing. This technique was developed by the Rock Island District and has been used in the Upper Mississippi River Navigation Study Reconnaissance Report, the Intracoastal Waterway Locks, Louisiana, Reconnaissance Report, as well as the Inland Navigation Investment Needs Assessment Study.

To determine the delay-tonnage relationship at a navigation lock deterministically, some approximations from queuing theory may be applied. If arrivals for service (locking) follow a Poisson process (i.e., randomly independent), then the expected wait for service (delay at lock) is given by the formula:

D = (U(S^2 + 1)P) / (2(1-U)), where:

D = expected delay;
S = ratio of the standard deviation to the mean processing time;

U = lock utilization defined as the ratio of the mean interarrival time and the mean processing time; and
P = mean processing time.

It can be seen from this formulation that as lock utilization approaches unity the expected delay at the lock grows without bound. The tonnage required to produce 100 percent utilization is defined as the "practical lock capacity."

The above demonstrates that expected delay can be related to lock utilization. It remains, however, to find the relationship between tonnage and expected delay. In order to accomplish this, a simultaneous system of equations was developed which models the relationship between tonnage and utilization. Solving this model for a given level of tonnage allows the corresponding utilization to be found and, hence, expected delay. By solving the model over a range of tonnages, the relationship between tonnage and expected levels of delay can be traced. Further, by "backsolving" the model, the tonnage required to produce any given level of expected delay can be determined.

The system of equations required to accomplish the above tasks is sufficiently complex to warrant a computer for solution. With this in mind, the model was developed using the software package TK Solver. This software's ability to iteratively solve (and backsolve) systems of equations make it a useful tool for developing and solving the model. The following discussion describes the implementation of the model.

STEP 1 - Base year tonnage is specified for each of ten commodity groups both upbound and downbound. The model contains equations specifying tonnage growth for each of the commodity groups. For any given level of total tonnage, these growth equations are solved to yield the tonnage in each commodity group. As a by-product of this solution, the year in which this tonnage is projected to occur is also found.

STEP 2 - The model has, as part of its input, the proportion of upbound and downbound tonnage in each commodity group and tons per barge load by commodity. This information is readily determined from available data sources. Using these inputs, along with the tonnage by commodity group from step 1, the number of loaded barges both upbound and downbound is determined.

STEP 3 - The imbalance between upbound and downbound tonnage necessitates the movement of empty barges. Moreover, even if movements were perfectly balanced, a certain percentage of the barges would still return empty; these are referred to as dedicated movements. The ratios of empty barges in each direction to loaded barge movements in the opposite direction is determined from historical data. These ratios are then applied to the number of empty barges traversing the lock.

At this point, the total number of barges traversing the lock, both upbound and downbound, is known. At sites where no alternate water routes are available these numbers inherently must be roughly equal and, although it is not an explicit requirement of the model, this is the case.

STEP 4 - Average tow size is determined from LPMS data and is held constant as traffic congestion increases. The physical limits of the waterway dictate a constant average tow size.

STEP 5 - Knowing both the total number of barges and average tow size permits the number of tows transiting the lock to be determined.

STEP 6 - The lockages types (i.e. single, double, multi-vessel, etc.) and the relative frequency with which they occur is determined largely from historical LPMS data. At several of the longer chamber locks, the proportion of multi-vessel lockages is projected to increase at higher levels of utilization. With the future proportion of multi-vessel lockages specified, the model determines the number of all other lockage types based upon historical data.

STEP 7 - An important model input is the lockage component times. These component times are input for the various lockage types, and entry/exit types. These were determined from LPMS data.

STEP 8 - The number of lockages of each type (i.e., single, double, etc.) has already been determined. It remains to determine the proportion of lockages that will use fly, turnback, or exchange approach/exits. Since we already assume that arrivals for lockage occur randomly, it follows that the portion of fly approach/exits is given by 1 minus utilization. If the lock utilization is less than .85, the model assumes that the lock operates using a First-Come-First-Serve policy and, hence, the proportion of turnback and exchange approach/exits are both equal to 1/2 of utilization. At higher levels of utilization, the model compares the relative efficiency of turnback versus exchange approach/exits and assigns the appropriate lockage policy--either 1-up 1-down, or k-up k-down. At locks where turnback is more efficient than exchange, the model assumes a gradual implementation of a k-up k-down policy until a 10-up 10-down policy is reached at 100 percent utilization. At locks where exchange is more efficient than turnback, a 1-up 1-down policy is gradually implemented so that it is fully in effect at 100 percent utilization.

STEP 9 - It should be noted that the analysis implies that utilization is known. Utilization, however, cannot be known since it is dependent (among other factors) on the relative proportion of exchange/exit types. This is why the iterative capabilities of TK Solver are essential. The calculations are done using an initial seed value (guess) for utilization. The results of this calculation allow the model to iteratively adjust the utilization value. After a number of iterations, the model converges on a solution which satisfies all the equations.

STEP 10 - Having determined the total number of tows, the proportion of each lockage type, and the proportion of each approach/exit type, the model sums the lockage component times to find the total time devoted to commercial lockages. Also, the average tow processing time, needed for the expected delay calculation, can now be determined.

STEP 11 - The total time used for non-commercial lockages is a model input based on historical data. It was assumed that this input would be constant through the period of analysis.

STEP 12 - The time that the lock will be unavailable for locking of any type (stall time) was determined from historical data and assumed to remain constant.

STEP 13 - Lock utilization is determined by adding the total time the lock is being used for either commercial or non-commercial lockages to the time the lock is unavailable for lockages (stalls) and dividing by the total time in the navigation season.

STEP 14 - Delay is calculated using the queuing theory formulation previously mentioned. The ratio of the standard deviation to mean lockage time is obtained from historical data and assumed to remain constant. If applicable, an adjustment is made to delay to account for open pass conditions.

Although some variables in the above discussion are called input variables, the model is indifferent to which variables are input and which are output. As long as enough variables are specified to define a solution, TK Solver will find the values for the remaining variables.

The form of the delay equation used in the GEM requires capacity and expected delay at 50 percent utilization as input parameters. Lock capacity can be found by this model using 100 percent as an input value for utilization and allowing the model to solve for total tonnage. After capacity is determined, half of this value is input for tonnage and the model solves for the expected delay associated with that level of tonnage.

It should be noted that since the GEM uses a simplified form of the expected delay equation, there is some discrepancy between the expected delay computed in GEM and that found by this model. This difference, however, is well within the inherent uncertainty bounds of the analysis. It is neither possible, not desirable, to account for every phenomenon which affects expected delay at a lock. The model attempts to accommodate the most fundamental parameters.

Table 5 - 1 below displays the estimates of the lock capacities and expected delays at 50 percent utilization derived for the non-IHNC locks explicitly included in the modeled system.

SIMULATION APPROACH

SIMULATION SETTING

The ability of the IHNC lock to process navigation traffic is affected by the presence of two vehicular bridges and one vehicular/railroad bridge that span the Inner Harbor Navigation Canal. Moving south to north, the geographic order of these structures is as follows: the St. Claude Ave. vehicular bridge, the IHNC Lock, the Claiborne Ave. vehicular bridge, and the Florida Ave. vehicular/railroad bridge. Importantly, the St. Claude Ave. Bridge is located between the approach point (waiting point) for vessels ready for lock service entering from the Mississippi River and the lock chamber. The approach point for vessels entering from the MR-GO is located between the Claiborne and Florida Bridges.

Currently, both St. Claude and Florida are low-level bascule bridges that require lifting for the passage of every vessel. The Claiborne bridge is a mid-level that requires lifting for approximately 14 percent of navigation traffic. However, the future without-project condition includes replacement of the existing low-level Florida Bridge with a high-level vehicular bridge and a separate low-level railroad bridge which will remain in the lowered position until navigation requires it to be raised. For with-project conditions the structural configuration of the

Table 5 - 1

Delay Function Parameters
Non-IHNC Locks
(Deterministic Method)

Lock	Capacity (millions of tons)	Delay at 50% Utilization (hours)
Port Allen	40.6	0.80
Bayou Sorrel	31.5	0.90
Algiers	30.4	0.80
Harvey	14.8	0.93
Bayou Boeuf	37.7	0.30
Calcasieu	64.0	0.50

canal would be modified to also include 1) a new low-level bridge at St. Claude and a new chamber located between the Claiborne and the Florida bridges or 2) a new mid-level bridge at St. Claude and no chamber replacement.

MODEL STRUCTURE

The Sim model is written in SIMSCRIPT, a language developed specifically as an aid to simulation analyses. SIMSCRIPT is an event-based language. That is, the program monitors the system being modeled, and identifies the occurrence of the next event. Simulation time is automatically advanced to that next time.

Model Entities

SIMSCRIPT uses 'entities' to model the character of the system. In the current environment, these entities are:
-Vessel types
-Segments
-Locks
-Bridges
-Curfews

The vessel type entity specifies the attributes of the vessel including, arrival rates, physical characteristics, and breakout strategy. A vessel is created as a temporary entity, simulated only for as long as it is impacting on the lock system.

A segment in the system identifies a portion of the region. Segments are distinguished by location and function. The IHNC system is modeled as five segments:
- the westbound arrival queue
- the westbound staging area
- the lock
- the eastbound staging area
- the eastbound arrival queue.

A lock is a special type of segment. Because additional information must be specified for a lock segment, the decision was made to create an additional dual entity, carrying all of the lock-specific information.

A bridge may be created as a means to measure the potential impact of bridge operation policy. One special case of this is the curfew period. The model is written to allow the user to specify for each bridge any number of curfew periods which restrict operation - providing starting and ending times for each.

Model Components

With these entities in mind, a SIMSCRIPT program is written to identify the activity within the system. A typical program consists of three types of components--a preamble, events, and routines.

a. Preamble. The preamble is the core of the simulation, providing the global definitions for each entity class, each event, each routine, and all global variables and arrays.

b. Events. This program consists of five events--Q.ARRIVAL, SEG.ARRIVAL, LOCK.EXIT, NEW.DAY, and NEW.SEASON. These form the core of the simulation, driving the activity of the system.

Q.ARRIVAL simulates the arrival of a vessel to one of the system queues. At this point, the vessel is created, any relevant breakouts (tow cuts) are created and light boats (assist vessels) employed. If the vessel is a priority one, it is placed early in the queue. If the arrival is a fly arrival, the vessel moves immediately to the appropriate staging area--a calculation of travel time is made to determine the time of arrival of the vessel and an event SEG.ARRIVAL is scheduled. The time of the next arrival of a vessel of this type is determined, based on probabilistic methods.

SEG.ARRIVAL simulates the arrival of a vessel to an intermediate segment of the system. If the segment is a lock, a call is made to LOCK.ARRIVAL, a routine which will be described later. Otherwise, time of traversal to the next segment is calculated and another SEG.ARRIVAL is scheduled. If the next segment is a lock, a call is made to LOCK.FILLER, also described later. The departure of a vessel from a segment triggers a second SEG.ARRIVAL for a vessel to fill the vacancy to be created in the current segment.

A LOCK.EXIT simulates the departure of a vessel, or set of vessels, from the lock. Calculations are made to determine the time at which the lock will be available for subsequent service, routine LOCK.MASTER is called, and a SEG.ARRIVAL is scheduled for all vessels leaving the lock. If the lock departure represents the departure of the vessels from the system, routine SYST.EXIT is called instead.

Events NEW.DAY and NEW.SEASON are time monitoring events. NEW.DAY simply flags the start of a new day. NEW.SEASON flags the start of a new season, and initiates the usage of a new season-dependent chambering time.

c. Routines. In addition to the core events, the simulation package also consists of seven routines - MAIN, COLL.STATS, LOCK.ARRIVAL, LOCK.FILLER, LOCK.MASTER, RD.DATA, and SYST.EXIT. These routines, unlike the events, provide support for the events, performing much of the functionality of the system.

MAIN is the driver routine. A call is made to RD.DATA to input the data, and the first set of arrival events are created. In addition, initializations of the day and season are accomplished through MAIN.Simulation is initiated in this routine.

COLL.STATS is the statistics output routine. A call is made to COLL.STATS at the end of every season and at the completion of the iteration.

LOCK.ARRIVAL performs two functions when a SEG.ARRIVAL is identified as a lock arrival. First, usage statistics are tabulated. Second, a service time is calculated, to determine the time of the LOCK.EXIT.

LOCK.FILLER is called from SEG.ARRIVAL to determine a packing for the next usage of the chamber. Vessels are selected from the appropriate waiting queue, in priority order. LOCK.FILLER attempts to pack the chamber as fully as is practical.

LOCK.MASTER is responsible for determining assignments to the lock. Two policies are implementable in the program - first-come first-serve, and k-up k-down. Once LOCK.MASTER has determined which vessel(s) the lock will serve next, a SEG.ARRIVAL is scheduled.

RD.DATA is the data input routine.

SYST.EXIT controls the departure of a set of vessels from the system under study. All light boats are returned to their home base, traversing back through the lock.

MODEL INPUTS

The Sim model requires detailed timing information on all aspects of traffic transiting the system. In general, timing data fall into two categories. One is the "interference" effect of the vehicular bridge structures spanning the canal on traffic being processed through the lock. The other is the duration of the lockage itself which is comprised of several operational components. Finally, the model requires traffic data by different tow size classes in order to accurately estimate the performance and volume of system throughput. The following paragraphs will describe the inputs that were used and how they were developed.

Timing Data

a. Bridge Interference. One way in which a bridge affects navigation is when the bridge must be raised to allow navigation traffic to pass. Unless the operation of the bridge can be perfectly coordinated with the movement of the tow, some interference will result. The bridge operator must first wait for a sufficiently safe break in the vehicular traffic flow, lower the traffic barriers, and then raise the bridge to a safe height for navigation to pass. This operation is required for every vessel wishing to transit the IHNC Lock. Based on data collected specifically designed to measure this interference effect at the St. Claude Bridge, it has been estimated that this interference causes on average a delay per opening of approximately three minutes. This bridge interference estimate is used as an input in the Sim model. Consequently the model effectively adds three minutes to the total lockage time of each lock cycle.

A second way in which a bridge affects navigation is through curfews which prevent the raising of the bridge during selected hours of the day. If navigation requires the bridge to be raised in order to pass, the curfew will temporarily halt the flow of traffic. Currently, curfews exist at each of the three bridges. However, the effect of the St. Claude curfew is most significant given its low-rise elevation and immediate proximity to the lock chamber. Curfew period is an input into the Sim model and its effects are therefore captured by the model.

The future with-project condition, which entails building a larger lock north of Claiborne avenue, requires the St. Claude Avenue Bridge to be replaced for realignment purposes. Since the replacement bridge is proposed as a low-rise, all navigation traffic will require that the bridge be raised, as is the case currently for existing conditions. However, because the new chamber will be relocated northward in the canal from its present location, the approach point for traffic arriving from the Mississippi River would move to a point between the lock chamber and the St. Claude Bridge. As a result, the interference inherent in a low-rise bridge would not impact lock processing time because the interference would occur concurrently with another ongoing lockage. At Claiborne, the bridge level will be the same as it is now, however, with regards to bridge impacts on navigation, the bridge will now disrupt a greater percentage of traffic. By removing the existing lock and constructing a larger one north of Claiborne avenue, stages will necessarily rise under the new Claiborne bridge due to Mississippi River effects. As a result, this will require more bridge openings than is currently necessary to accommodate navigation. Analysis of stage and tow height distributions has shown that approximately 26 percent of navigation traffic would require the Claiborne bridge to open under this with-project condition.

b. Lockage Times. A lockage is comprised of a series of events that are required to transfer a vessel or tow through a lock in a single direction. Timing information for each of these events was calculated using 1988 - 1991 LPMS data and a 50 - year period of record for relevant stage data in order to capture the impact of water levels on lock operations. The following is a brief description of each lockage event.

Approach time: The difference between the time the lock is ready to serve the incoming vessel and the time when the bow of the inbound vessel is abreast of the lock gates and it is in a position parallel to the guide wall to enter the lock chamber. The three possible types of approaches are:

1. Fly Approach: The lock has been idle and the inbound vessel directly enters the chamber.

2. Exchange Approach: The vessel inbound to the chamber passes a vessel outbound from the chamber.

3. Turnback Approach: The proceeding event is a lockage in which no tows were served.

Entry Time: Time from bow over sill to end of entry. Usually the end of entry takes place when the tow or the entering cut is secured within the lock and the gates are clear.

Chambering time: The time required to completely fill or empty the lock chamber.

Exit Time: The time from start of exit to end of lockage. This is the difference between the time when the gates are fully open, and when the indication to proceed is given, and the time when the lock has completed serving a vessel or cut and can be dedicated to another vessel or cut. As with the approach time there are three types of exit.

1. Fly Exit: The lock will be idle following the departure of the outgoing vessel.

2. Exchange Exit: The vessel outbound from the chamber passes a vessel inbound to the chamber.

3. Turnback Exit: The vessel to be served next is going in the same direction as the outbound vessel and the lock must be turned back with no vessels in the chamber.

Added time for Multivessel Lockages: A multivessel lockage occurs when more than one commercial vessel or tow is served in a single lockage cycle. As a result, the additional time it takes to process the additional vessels must be taken into account.

IHNC Lock data was used in the production of these component times for the without-project condition. However, in order to evaluate improved lock conditions, data on the Bayou Boeuf lock (1200 ft long) was used to represent all 1200 ft long lock scenarios for entry and exit times. This adjustment is necessary because entering and exit times, for the most part, are a function of lock length. The midpoint between the Bayou Boeuf lock times and the existing lock (640 ft long) times were used to represent all 900 ft long lock scenarios.

A multivessel lockage occurs when more than one commercial vessel or tow is served in a single lockage cycle. As a result, the additional time it takes to process the additional vessel(s)/tow(s) must be taken into account. Using the same four years of LPMS data, in the manner described above, the additional time for multivessel lockages were calculated for the existing lock (5 minutes), all 900 ft long locks (7.5 minutes) and all 1200 ft long locks (10 minutes).

The Sim model is structured such that the approach, entering and exit times to be used for each tow size class must be exclusive of bridge interference time since this effect is separately entered as a model input. These lockage times by tow class (described in subsequent paragraphs) are presented in table 5 - 2.

Table 5 - 3 displays the estimated chambering times by lock size, broken down into four seasons or quarters. Chambering time varies over the course of a year as a result of changing head conditions produced by Mississippi River stages. Variation in chambering time is the predominate reason for seasonal differences in average delay. In order to capture this seasonal effect, chambering times are specified on a quarterly basis. In developing the chambering times displayed in table 5 - 3, a 50-year period of record for stage data and chamber size

Table 5 - 2

Average Lock Component Times by Lockage Type and Towsize Class
(Single Vessel Lockage)

Tow Sizes				Existing Lock			1200 ft Locks			900 ft Locks		
				Approach	Entry	Exit	Approach	Entry	Exit	Approach	Entry	Exit
Class	Length (ft)	Width (ft)		(minutes)			(minutes)			(minutes)		
1	>=140 and <=223	>=30 and <=40	Fly	8	6	5	8	4	5	8	5	5
			Exchange	8	6	6	8	4	6	8	5	6
			Turnback	4	6	6	4	4	5	4	5	5.5
2	>=140 and <=213	>=41 and <=60	Fly	6	9	7	6	4	6	6	6.5	6.5
			Exchange	9	9	7	9	4	6	9	6.5	6.5
			Turnback	4	9	8	4	4	4	4	6.5	6
3	>=224 and <=297	>=30 and <=40	Fly	8	6	5	8	4	6	8	5	5.5
			Exchange	8	6	6	8	4	7	8	5	6.5
			Turnback	4	6	6	4	4	6	4	5	6
4	>=214 and <=299	>=41 and <=60	Fly	6	9	7	6	4	6	6	6.5	6.5
			Exchange	9	9	7	9	4	8	9	6.5	7.5
			Turnback	4	9	8	4	4	7	4	6.5	7.5
5	>=230 and <=319	>=61 and <=70	Fly	6	9	7	6	3	7	6	6	7
			Exchange	9	9	7	9	3	6	9	6	6.5
			Turnback	4	9	8	4	3	0	4	6	8
6	>=298 and <=419	>=30 and <=40	Fly	8	6	5	8	5	6	8	5.5	5.5
			Exchange	8	6	6	8	5	8	8	5.5	7
			Turnback	4	6	6	4	5	6	4	5.5	6
7	>=300 and <=389	>=41 and <=60	Fly	6	9	7	6	5	7	6	7	7
			Exchange	9	9	7	9	5	8	9	7	7.5
			Turnback	4	9	8	4	5	8	4	7	8
8	>=320 and <=436	>=61 and <=70	Fly	6	9	7	6	15	8	6	12	7.5
			Exchange	9	9	7	9	15	0	9	12	7
			Turnback	4	9	8	4	15	0	4	12	8
9	>=420 and <=469	>=30 and <=40	Fly	8	6	5	8	5	8	8	5.5	6.5
			Exchange	8	6	6	8	5	8	8	5.5	7
			Turnback	4	6	6	4	5	7	4	5.5	6.5
10	>=390 and <=469	>=41 and <=60	Fly	6	9	7	6	6	8	6	7.5	7.5
			Exchange	9	9	7	9	6	8	9	7.5	7.5
			Turnback	4	9	8	4	6	8	4	7.5	8
11	>=437 and <=459	>=61 and <=70	Fly	6	9	7	6	8	9	6	8.5	8
			Exchange	9	9	7	9	8	12	9	8.5	9.5
			Turnback	4	9	8	4	8	10	4	8.5	9

Table 5 - 2

Average Lock Component Times by Lockage Type and Towsize Class
(Single Vessel Lockage)

Tow Sizes				Existing Lock			1200 ft Locks			900 ft Locks		
				Approach	Entry	Exit	Approach	Entry	Exit	Approach	Entry	Exit
Class	Length (ft)	Width (ft)		(minutes)			(minutes)			(minutes)		
12	>=470 and <=619	>=30 and <=40	Fly	8	6	5	8	7	7	8	6.5	6
			Exchange	8	6	6	8	7	9	8	6.5	7.5
			Turnback	4	6	6	4	7	7	4	6.5	6.5
13	>=470 and <=540	>=41 and <=60	Fly	6	9	7	6	6	8	6	7.5	7.5
			Exchange	9	9	7	9	6	9	9	7.5	8
			Turnback	4	9	8	4	6	9	4	7.5	8.5
14	>=460 and <=552	>=61 and <=70	Fly	6	9	7	6	7	8	6	8	7.5
			Exchange	9	9	7	9	7	9	9	8	8
			Turnback	4	9	8	4	7	11	4	8	9.5
15	>=620 and <=650	>=30 and <=40	Fly	4	12	8	4	6	8	4	9	8
			Exchange	9	12	8	9	6	9	9	9	8.5
			Turnback	5	12	9	5	6	8	5	9	8.5
16	>=541 and <=602	>=41 and <=60	Fly	6	9	7	6	7	9	6	8	8
			Exchange	9	9	7	9	7	10	9	8	8.5
			Turnback	4	9	8	4	7	8	4	8	8
17	>=553 and <=619	>=61 and <=70	Fly	6	9	7	6	8	11	6	8.5	9
			Exchange	9	9	7	9	8	21	9	8.5	14
			Turnback	4	9	8	4	8	21	4	8.5	14.5
18	>=603 and <=657	>=41 and <=60	Fly	4	12	8	4	7	8	4	9.5	8
			Exchange	9	12	8	9	7	9	9	9.5	8.5
			Turnback	5	12	9	5	7	10	5	9.5	9.5
19	>=620 and <=640	>=61 and <=70	Fly	4	12	8	4	9	8	4	10.5	8
			Exchange	9	12	8	9	9	11	9	10.5	9.5
			Turnback	5	12	9	5	9	13	5	10.5	11
20	>=641 and <=680	>=61 and <=70	Fly	4	12	8	4	9	8	4	10.5	8
			Exchange	9	12	8	9	9	12	9	10.5	10
			Turnback	5	12	9	5	9	10	5	10.5	9.5

Table 5 - 3

Average Chambering Times by Season
(Minutes)

Locksize	1st Quarter CY	2nd Quarter CY	3rd Quarter CY	4th Quarter CY
Existing Lock	10.3	10.0	7.8	7.5
900 x 90 x 22	7.8	8.2	6.6	6.6
900 x 110 x 22	8.0	8.4	6.8	6.8
900 x 100 x 36	9.1	9.7	6.8	6.7
1200 x 90 x 22	7.8	8.2	6.6	6.6
1200 x 100 x 22	8.0	8.4	6.8	6.8
1200 x 100 x 36	9.1	9.7	6.8	6.7